

## Sunspot Observations and Counting at Specola Solare Ticinese in Locarno since 1957

Sergio Cortesi<sup>1</sup> · Marco Cagnotti<sup>1</sup> ·  
Michele Bianda<sup>2</sup> · Renzo Ramelli<sup>2</sup> ·  
Andrea Manna<sup>1</sup>

© Springer ....

### Abstract

Specola Solare Ticinese is an observatory dedicated to Sunspot Number counting, which was constructed in 1957 in Locarno, Southern Switzerland, as an external observing station of the Zurich Federal Observatory. When in 1981 the responsibility of the determination of the International Sunspot Number was assumed by the Royal Observatory of Belgium, Specola Solare Ticinese was given the role of pilot station, with the aim of preserving the continuity in the counting method. We report the observing procedure and counting rules applied in Locarno.

**Keywords:** Sunspots, Statistics; Solar Cycle, Observations

### 1. The Specola Solare Ticinese: A Historical Overview

Systematic sunspot observations have been carried out in Locarno, Switzerland, since the mid-1930s and were started by Karl Rapp (Figure 1, left panel), the engineer who founded the Rapp Motorenwerke GmbH in Munich, which afterwards became BMW. Rapp retired in Locarno in 1934 and developed his skills in astronomy using a 14 cm aperture Merz refractor. His sunspot drawings, sent to William Brunner at the Zurich Observatory, opened a collaboration that was continued by Max Waldmeier. The two Zurich researchers could appreciate the favorable weather conditions in Locarno which frequently were complementary on the north and south side of the Alps, due to the meteorological foehn effect. Based on this positive experience, Waldmeier decided to build in Locarno

---

✉ Cagnotti  
cagnotti@specola.ch

<sup>1</sup> Specola Solare Ticinese, Via ai Monti 146, CH-6605 Locarno, Switzerland

<sup>2</sup> Istituto Ricerche Solari Locarno, Via Patocchi, CH-6605 Locarno-Monti, Switzerland



**Figure 1.** On the left panel, Karl Rapp observing the sun at Locarno with his 14 cm aperture Merz refractor. On the right panel, Sergio Cortesi, Max Waldmeier, and Araldo Pittini at the entrance of Specola Solare Ticinese, picture taken in 1961. (Photo credit: S. Cortesi).

the Specola Solare (Figure 2), which was inaugurated in 1957 during the International Geophysical Year. The main instrument was the 15 cm aperture Coudé-Zeiss refractor. This instrument was never changed and is still used now to produce daily sunspot drawings based on the projection technique (25cm diameter projected image, Figure 3 and Figure 4 ). The first observers at Specola Solare were Sergio Cortesi, who already had scientific contacts with Rapp, and Araldo Pittini (former observer at Zurich Observatory).

Waldmeier used to spend several weeks per year working in Locarno together with Cortesi and Pittini, thus having many opportunities to instruct them about the counting method and showing them how he was counting. He was pointing out the concept that the main goal for an observer was to find a constant method of counting. He was not in the habit of giving strong rules on how a single spot had to be taken into account. However the observers, were invited to check the quality of their work, regularly comparing their average counting values with Waldmeier's results. After an initial learning period, since 1964 the counting method of Locarno's observers was giving on average the same results as Waldmeier. It is worth highlight, that Cortesi and Pittini developed different personal counting strategies, which gave different results on a day to day basis, but wich were in agreement on average over scales of one month or longer. The observations obtained in Locarno could often fill the gaps due to bad weather conditions in Zurich.



**Figure 2.** The Specola Solare observatory just after its construction in 1957. In the background is the building of the Swiss Meteorological Institute. (Photo credit: S. Cortesi).

After Waldmeier’s retirement in 1979, ETH Zurich decided to stop the sunspot counting activity and to close Specola Solare. The determination of the Wolf number, until then always under the responsibility of the Zurich Observatory, was assigned by the International Astronomical Union to the Sunspot Index Data Center (SIDC) at the Royal Observatory of Belgium. The Wolf number was then renamed *International Relative Sunspot Number*,  $R_i$ . Specola Solare could continue independently his activity managed by a local association named Associazione Specola Solare Ticinese. Sergio Cortesi was acting as main observer and gave instructions to several additional collaborators on the method of counting that he learned under Waldmeier’s guidance. From 1981 Specola Solare Ticinese assumed the role of pilot station of SIDC (Clette *et al.*, 2014; Stenflo, 2016) in order to minimize the risk of jumps in transferring the determination of  $R_i$  from Zurich to Brussels. Since 2012 the role of main observer at Specola Solare Ticinese has been assumed by Marco Cagnotti after a few years of parallel observations with Cortesi, and an in-deep instruction on the method transmitted by Waldmeier. When Cagnotti is unavailable, drawings are still performed by Cortesi or other collaborators who have already been active for decades.

## 2. Observing and Counting Method

The International Relative Sunspot Number is determined with the formula introduced by Wolf (1851, 1856):

$$R_i = k(10N_G + N_S) \quad (1)$$

where  $N_G$  is the number of groups,  $N_S$  the total number of counted sunspots and  $k$  a scaling factor depending on the instrument and on the observer. If weather conditions allow, observations at Specola Solare Ticinese are performed daily before 12 UT using the 15 cm aperture Coudé-Zeiss refractor, which is diaphragmed to 8 cm for a better contrast at the specific local conditions. A

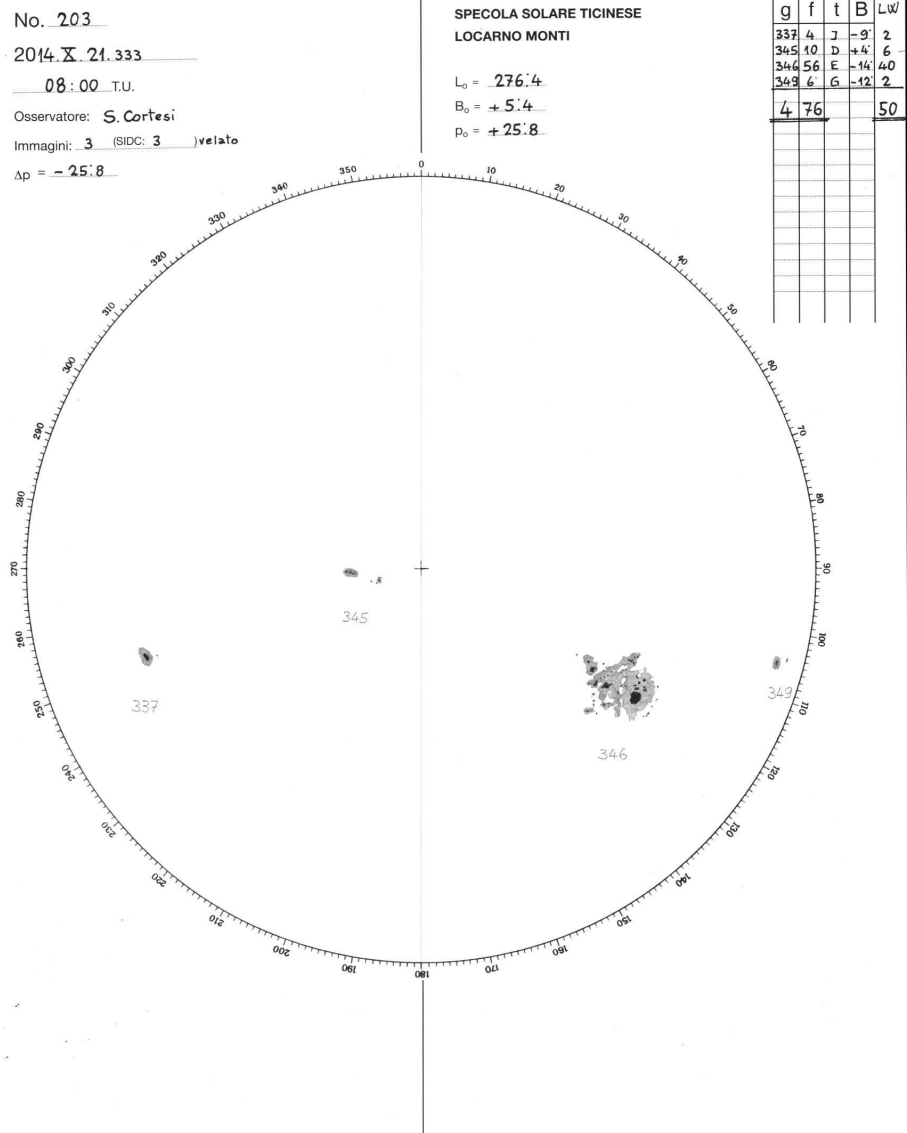


**Figure 3.** Observer Marco Cagnotti when drawing. (Photo credit: S. Cortesi).

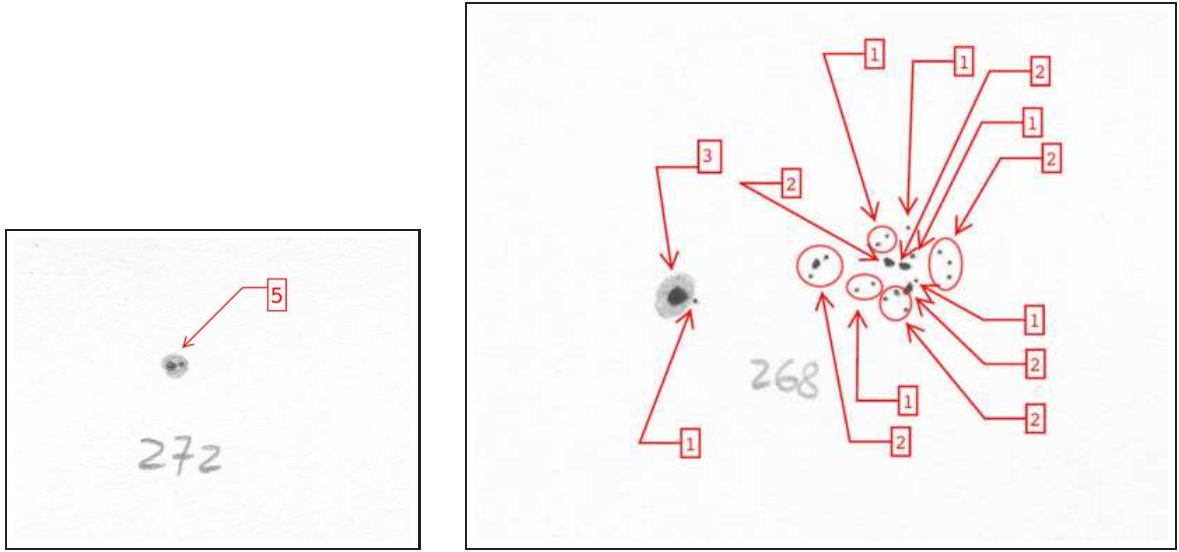
projected solar image with 25 cm diameter is obtained on a metallic screen on which a drawing paper sheet is fixed, oriented with respect to the heliographic axis (see Figures 3 and 4). The observer draws the sunspots with a pencil. The meteorological situation influences the procedure: in the case of a partially cloudy sky with short appearances of the Sun, one is forced to observe quickly, while with a clear sky, the observer knows that they can take their time. In order to distinguish paper sheet imperfections from real solar structures, when needed the observer moves a second sheet quickly back and forth above the drawing sheet. This is important in particular to decide when there is a penumbra, and to find small sunspots. An experienced observer is able to take advantage of a fraction of a second of good seeing. It is thus possible to obtain a drawing corresponding to a photographic image taken with better seeing quality. While the observers are drawing, they are already interpreting the observation, deciding about the group division and doing the counting of the spots in each group.

The original counting method taught by Waldmeier to the Specola observers provides for different weights according to the sunspot size.

- a small sunspot is counted as 1
- a larger sunspot without penumbra is counted as 2
- a small spot with penumbra and only an umbra is counted as 3
- a big spot with penumbra and only an umbra is counted as 4 or 5
- a spot with penumbra and 2 umbra is counted as 5
- more complex sunspots with penumbra and more than two umbrae are counted more than 3, generally the main umbra is counted as 3 and the others are counted as 2 or as 3 depending on the size.



**Figure 4.** Example of a sunspot drawing. On top of the drawing sheet the following data are reported: on the left is the observing information, in the central column are the solar ephemerides, and on the right table are the group data, including the sequential group number, weighted counting of sunspots, classification, latitude, and unweighted counting.



**Figure 5.** Examples of counting. Here an example on how Cagnotti counted two groups reported on the drawing of 26 October 2015.

- nearby small sunspots can be counted only partially, also taking into account the observing conditions: seeing quality, foggy sky, clear sky, cloudy sky. It can thus happen that the number of sunspots drawn is larger than the counting.

Examples of how the weighted counting is applied can be seen in Figure 5.

The origin of the weighting method presents some uncertainties. The first known written documentation is by Waldmeier (1948) (see also Waldmeier, 1968). However there are some hints that at least his predecessor Brunner already considered the weighing possibility. In fact we know that Rapp was already using the weighted counting method based on Brunner’s instructions (private communication of Karl Rapp to Sergio Cortesi before 1957).

Since 2012 at Specola Solare Ticinese we started also an unweighted counting method where each sunspot is counted as 1 independently of the size and of the presence of a penumbra. In the case of a complex sunspot, with penumbra, each umbra is counted as 1. This counting is applied later, in the office, counting on the drawing. The impact of weighting with respect to the unweighted counting was studied by Svalgaard (2016).

As reported above, the observer also has to decide the grouping of sunspots. During moderate activity periods this task is in general easy, because the groups are well separated on the solar disk. However during high activity periods this could be difficult, because several groups are close to each other or even partially overlapped. Hints can be given by Joy’s law, which states the group’s tendency to be “tilted” towards the Equator. The Zurich group classification (Waldmeier, 1947) is used as well, considering the evolution of the groups and looking at the

drawings of the previous days. It has to be pointed out that in the grouping task the observer must avoid taking advantage of data not available in Wolf's epoch, such as magnetograms or online high resolution images.

Once the drawing is completed, the observer inserts further information on the sheet, including the seeing quality in a scale going from 1 (best quality) to 5 (bad conditions generated by strong air turbulence) and the observing time with a resolution of a quarter hour. In addition, the following data of each group are reported in a table: sequential group number (the numbering is restarted each new year), counted number of sunspots (weighted and unweighted), classification, and latitude.

The total and the hemispheric weighted and unweighted counting values are delivered daily to SIDC. The drawings are also published online on the Specola web site (<http://www.specola.ch/e/drawings.html>). The archive includes all the drawings since 1981.

Weather conditions in Locarno allows us to obtain on average 306 drawings per year.

**Acknowledgments** The association ASST organizes the financing of Specola Solare Ticinese and was established by Alessandro Rima (who directed it from 1980 until 1991) and Paul Utermohlen. Jan Olof Stenflo at ETHZ recommended using Specola Solare Ticinese as the pilot station for SIDC in Brussels. Since 1992, ASST has been directed by Philippe Jetzer. Specola Solare Ticinese is mainly financed by Ticino Canton through the Swisslos found. We thank Mario Gatti for helpful discussions.

## References

- Clette, F., Svalgaard, L., Vaquero, J.M., Cliver, E.W.: 2014, Revisiting the Sunspot Number. A 400-Year Perspective on the Solar Cycle. *Space Sci. Rev.* **186**, 35–103. doi:10.1007/s11214-014-0074-2.
- Stenflo, J.: 2016, Transition of the Sunspot Number from Zurich to Brussels in 1980: A personal perspective. *Solar Phys.* **this issue**.
- Svalgaard, L.: 2016, The Effect of Sunspot Weighting. *Solar Phys.* **this issue**.
- Waldmeier, M.: 1947, Heliographische Karten der Photosphäre für das Jahr 1946. *Publikationen der Eidgenössische Sternwarte Zürich* **9**, 1.
- Waldmeier, M.: 1948, 100 Jahre Sonnenfleckenstatistik. *Astron. Mitteil. Eidgn. Sternw. Zürich* **152**.
- Waldmeier, M.: 1968, Die Beziehung zwischen der Sonnenflecken-relativ-zahl und der Gruppenzahl. *Astron. Mitteil. Eidgn. Sternw. Zürich* **285**.
- Wolf, R.: 1851, Sonnenflecken Beobachtungen in der zweiten Hälfte des Jahres 1850. *Mitt. Nat.forsch. Ges. Bern* **207**, 89–95.
- Wolf, R.: 1856, Mitteilungen über die Sonnenflecken. *Astron. Mitteil. Eidgn. Sternw. Zürich* **1**, 3–13.